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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest)

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Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, distribution, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in environmental impact assessment. The Pismo clam (Tivela stultorum) supports an important sport fishery in the Pacific Southwest region, but has no present commercial importance. This review describes the life history (spawning, eggs and larval stages, postlarvae and juveniles, maturity, and life-span), growth characteristics, former commercial and sport fisheries, ecological role, and environmental requirements.

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

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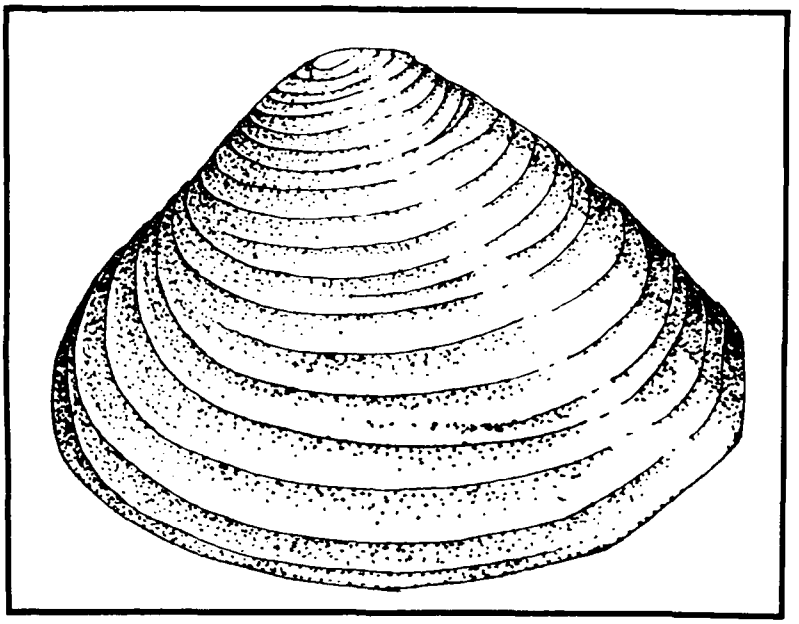

Figure 1. Pismo clam.

PISMO CLAM

NOMENCLATURE/TAXONOMY/RANGE

Scientific name . . . . . Tivela stultorum (Mawe 1823)
Preferred common name . . . Pismo clam (Figure 1)
Other common name . . . . Giant tivela
Class . . . . . Bivalvia
Order . . . . . Veneroida
Family . . . . . Veneridae

Geographic range: The Pismo clam is rare to common (in the low intertidal zone and offshore to a depth of 10-25 m) along the Pacific coast from Monterey Bay (Figure 2) to Bahia Magdalena, Baja, California (Fitch 1953).

MORPHOLOGY/IDENTIFICATION AIDS

The shell of the Pismo clam reaches lengths of 150 mm or more, is strong, heavy, and generally smooth though sculptured with fine concentric growth lines; beak nearly central; ligament obvious, elongate, set in deep groove; periostracum shiny, greenish to brownish; shell pale buff to dark chocolate, occasionally marked with brown or purple-brown bands (Morris et al. 1980).

REASON FOR INCLUSION IN SERIES

The Pismo clam supports an important sport shellfishery. An estimated 150,000 people once sought the clams on Pismo Beach, California, during a single weekend (Frey 1971); however, sea otters have depleted the supply there since 1981, and as of 1986 there is no fishery (A.W. Haseltine, Calif. Fish and Game; pers. comm.).

The Pismo clam lives in the sandy beaches along the Central and Southern California coast -- a habitat that is highly vulnerable to degradation from

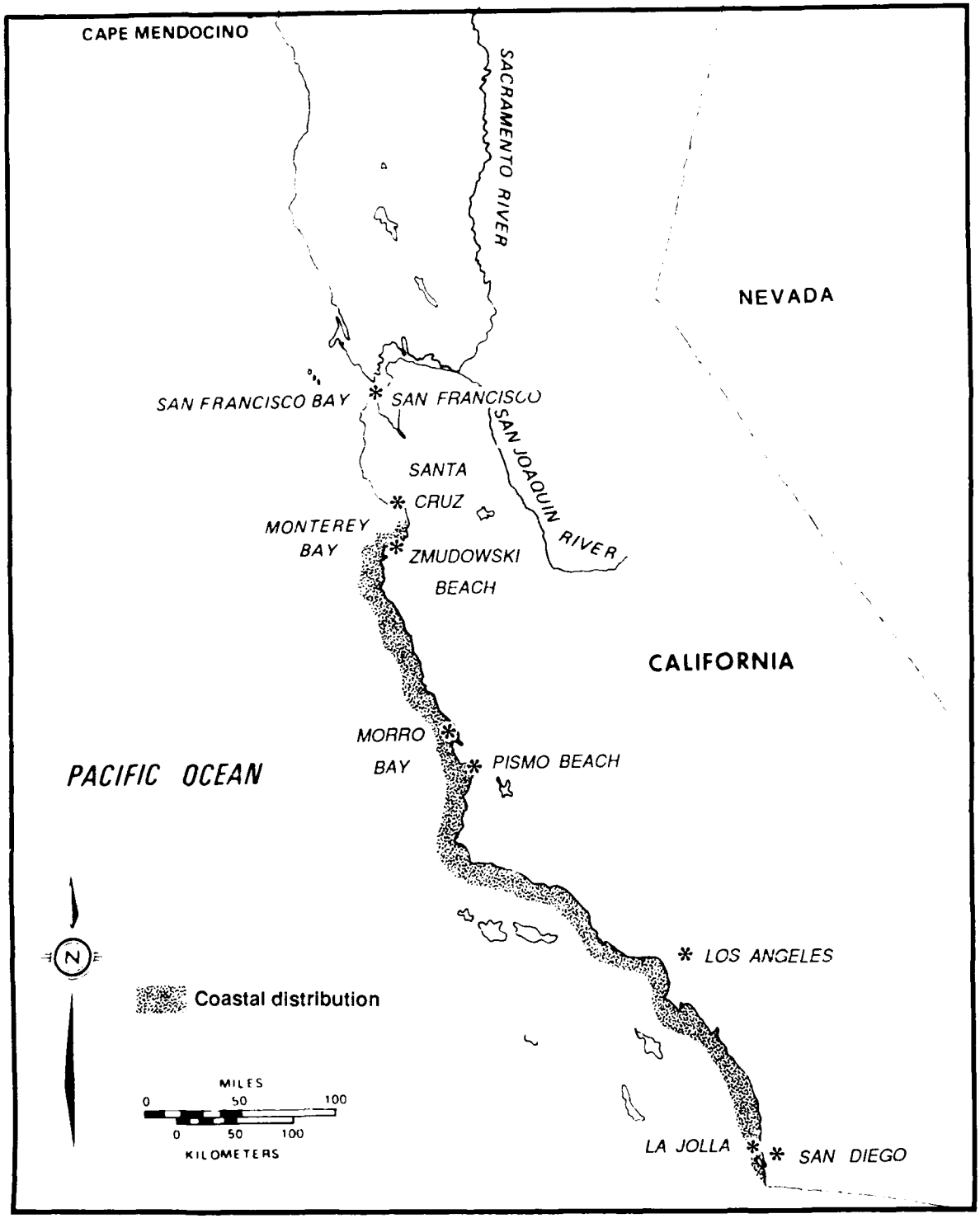

Figure 2. Distribution of the Pismo clam along the California coast. The clam only occurs on broad sandy beaches exposed to strong surf within the range indicated on the map. Also, the clam sometimes occurs in entrances to bays, sloughs, and estuaries.

dredging and oil pollution (oil spills). Substantial losses of clam populations resulting from man's manipulation of the coastal zone could be expected to cause an economic loss to the sport fishery.

In many areas, recruitment of Pismo clams has been very low and the population has declined almost steadily over years. Exact causes for lack of recruitment are not fully known. Further losses of parent stocks from degradation and/or overfishing could be expected to further reduce this important recreational shellfishery.

LIFE HISTORY

Spawning

The sexes of the Pismo clam are separate (Fitch 1961) although early investigators believed the clam to be hermaphroditic (Weymouth 1923). Most clams become sexually mature after their first winter, at shell length as short as 17-20 mm (Coe 1947). Gametogenesis begins in March or April and ripe gametes first appear in April and May. Gonadal development proceeds rapidly in June and July; spawning begins in late July or early August and continues to the end of November (Coe 1947). Nybakken and Stephenson (1975) found that the main spawning of clams at Pismo Beach and Monterey occurred during September and October with some occurrence from June to August. Coe (1947) found a similar spawning cycle for clams from San Diego.

Discharge of gametes appears to take place when there is a fair rise in water temperature (Fitch 1961). As in most bivalves, males usually spawn first and their release of gametes stimulates the females to spawn. Spawning may occur several times during the season since only a portion of the gametes ripen at one time. Hermaphrodites are rare. Out of 289 clams examined, only three hermaphrodites were found (Nybakken and Stephenson 1975).

Fecundity and Eggs

The eggs of Pismo clams are very small, 0.074-0.081 mm in diameter (Coe and Fitch 1950). The number of eggs per female increases with shell size, ranging from 10 to 20 million and averaging 15 million (Coe 1953; Fitch 1957; Fitch 1961). Earlier, Weymouth (1923) estimated the number of eggs per female to be 47 to 98 million.

Larvae

Little is known about the Pismo clam from the time eggs are spawned until the clams appear on the beach. The free swimming larval life is estimated to last for 3 weeks (Coe 1947) during which the larvae can be swept alongshore for 40 to 100 miles. Larvae and postlarvae less than 2.3 mm have never been found drifting in the sea. Recent findings at the California Fish and Game, Marine Resources Laboratory, Granite Canyon, California, indicate that the larvae have a high weight/volume ratio and may remain on or near the bottom most of the time and move very little.

Postlarvae and Recruitment

At metamorphosis the clam develops a foot and attaches to sand grains with a byssus. This attachment helps the clam to maintain itself in the constantly moving sand of a wave-beaten coast (Weymouth 1923). The length of a byssus can range from 45 to 92 mm or as much as five times the length of the clam. As the clam increases in size the byssus disappears. The clam's increasing weight and burrowing power then helps to maintain it on the beach.

Recruitment was examined in the Pismo Beach area beginning in 1919, and a survey was conducted annually from 1925 to 1965 except for during

1942-45 (Weymouth 1923; Herrington 1929; Alpin 1947a; Bureau of Marine Fisheries 1948; Collyer 1951; Fitch 1952, 1954, 1955; Baxter 1961, 1962; Carlisle 1966). Young-of-the-year and adults of all ages were sampled during the surveys (Table 1).

Pismo clams were sampled at three locations: 100 yd north of the pier at Pismo Beach; 1.1 mi south of the pier (Oceano section); and 0.5 mi south of the north boundary of the clam refuge (Le Grande section). The sampling sections or transects were

Table 1. Number of clams, by age groups, taken in three sections on Pismo Beach surveyed each year, 1925-65.

Year of survey	Age (years)									Total
	0	1	2	3	4	5	6	7	≥8	
1925	23	265	6	17	5	5	7			328
1926	53	15	87	3	5	1		1		165
1927	38	61	27	23		1				150
1929	6	32	40	24	15					117
1929	472	5	23	23	7					545
1930	360	188	5	4	6	4	3			570
1931	885	157	58	2	3	3	1			1,109
1932	44	277	125	99	28	3	2			578
1933	199	38	122	99	110	52	25	2		647
1934	1	70	23	81	81	31	8	4	1	300
1935	770	6	57	15	69	41	23	6	2	989
1936	144	368	3	45	9	56	28	17	12	682
1937	747	102	247	8	19	7	32	15	2	1,179
1938	9	233	96	175	7	11	9	6	2	548
1939	24	4	54	75	143	2	5	4	7	318
1940	25	34	11	19	29	85	11	8	30	252
1941	19	6	7	1	2	6	23	3	13	80
1946	607	167	57	204	220	51	21	8	13	1,348
1947	32	295	101	67	149	90	25	5	8	772
1949	1	7	53	191	65	73	52	13	15	470
1951			3	2	31	72	41	23	17	189
1953		77			1	12	15	05	61	231
1954	3	1	40	8			8	11	92	163
1955	3	10	5	19	2	1	2	1	80	123
1956		2	5	2	42				31	82
1957	653			6	10	16	1		20	706
1958	8	79			3		7		2	99
1959	206	55	63					9	12	345
1960	49	66	34	32		1			6	188
1961	11	25	38	27	9				2	112
1962	71	31	16	25	26	6			1	176
1963	79	25	36	15	16	64			2	179
1964	382	53	45	17	12	6	2		1	518
1965	241	279	73	36	3	5				637

16 cm wide and 20 cm deep, and extended across the beach from high tide line to as low as it is possible to dig during one of the lowest tides of the year.

Sets of clams at Pismo Beach, as indicated by the number of young-of-the-year collected (Table 1), were good in 1929-31, 1935, 1937, 1946, 1957, 1959, 1964, and 1965, and poor in 1928, 1934, 1938, 1949, 1951, 1953, 1955, 1956, and 1961. In later years (after 1965), setting in the Pismo Beach area was extremely poor (James Hardwick, Calif. Fish and Game; Pers. comm.). Causes for these erratic setting patterns are not known. Coe (1953) speculated that the variable recruitment was due to the vagaries of the ocean currents that bring larvae to the beach at the end of the pelagic stage.

Maturity and Life Span

Pismo clams mature during the first full summer of life at La Jolla, California, and during the second summer of life in the northern euge of their range. They are 17 mm to 31 mm long at first maturity (Coe and Fitch 1950). Morris et al. (1980) wrote that females spawn for the first time in the second or third summer after hatching.

The age of the Pismo clam can be determined by rings on the shell (Figure 1). The rings used in age determination are usually formed in fall or winter, or when the clam is subjected to the most prolonged period of disturbances. The longest clam on record at Pismo Beach was seven and three-eighths inches long and was about 26 years old, but the ages of a number of clams from Baja California have exceeded 35 years. Gillilan (1964) recorded a 53-year-old clam at Zuma Beach, California, that measured only five and one-quarter inches long.

GROWTH CHARACTERISTICS

The Pismo clam grows continuously throughout its life (Fitch 1950). Increase in shell growth is greatest in spring, summer, and early fall. The average yearly increase in length during the first 4 years of life is slightly more than 20 mm. At age 10 the annual increase is usually not more than 5 mm. Minimum legal length on most beaches (4.5 inches) is first reached in 5 years but may not be reached until 8 or 9 years. At Pismo Beach, clams reach legal minimum length between ages 7 and 8 (Figure 3).

Growth rates apparently vary among beaches. Herrington (1929), who constructed growth curves for clams from four beaches between Morro and Monterey Bays (Figure 4), reported that clams from Turtle Bay grew fastest and those from Morro Bay slowest.

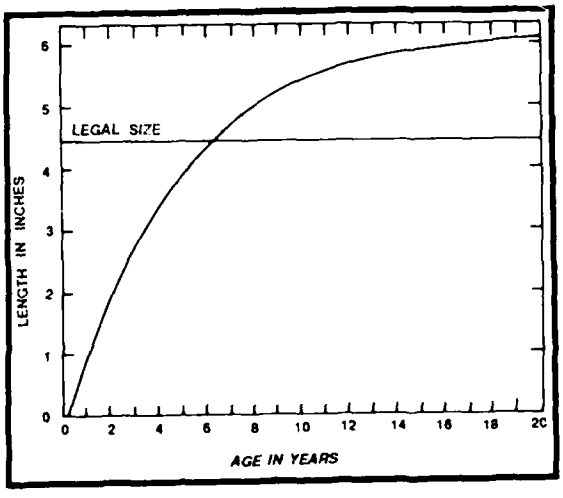

Figure 3. Growth of Pismo clams at Pismo Beach. These averages have been determined from the results of the annual census for the years 1923 through 1949, excluding 1942 through 1945 (Fitch 1950).

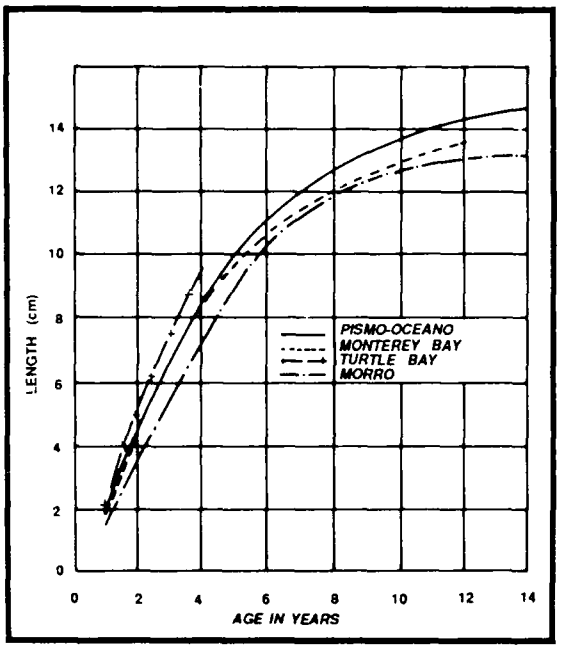

Figure 4. Growth curves for Pismo clams from Pismo-Oceano Beach, Morro Beach, Monterey Bay, and Turtle Bay (Herrington 1929).

COMMERCIAL AND SPORT FISHERIES

Pismo clams have been gathered and used over the past 2,000 years, as judged by the occurrence of their shells in Indian kitchen middens (heaps of shells and other refuse) along the California coast. Initially these clams were eaten and shells were used as ornaments or as household aids for digging or scraping (Frey 1971).

In the early 1900's, teams of horses pulling plows were used to collect clams commercially from Pismo Beach to Imperial Beach. The clams were loaded in wagons and later fed to hogs and chickens (Frey 1971).

On the basis of the records maintained from 1916 to 1947 (Table 2), it was estimated that 6.25 million lb of clams were harvested by commercial diggers during this period (Fitch 1954). The average annual catch was nearly 100,000 lb, and the highest was 665,684 lb in 1918.

Table 2. Yearly landings of Pismo clam in thousands of pounds (round weight).

Year	Calif.	Shipments[a]	Total pounds
1916	220.6		220.6
1917	502.1		502.1
1918	665.7		665.7
1919	417.5		417.5
1920	299.0		299.0
1921	219.5		219.5
1922	193.5		193.5
1923	237.9		237.9
1924	293.1		293.1
1925	323.2		323.2
1926	274.3		274.3
1927	133.0		133.0
1928	125.8		125.8
1929	109.7		109.7
1930	108.9		108.9
1931	104.7		104.7
1932	110.3		110.3
1933	106.2		106.2
1934	140.7		140.7
1935	181.9	14.2	196.1
1936	209.8		209.8
1937	224.0		224.0
1938	214.6		214.6
1939	192.7		192.7
1940	167.5		167.5
1941	168.8	86.7	255.5
1942	93.6	727.8	821.4
1943	45.9	4,526.1	4,572.0
1944	34.5	11,719.8	11,754.3
1945	26.1	53,414.2	53,440.3
1946	69.2	11,408.5	11,477.7
1947	60.6	1,279.7	1,340.3

[a]From south of the international boundary. Cleaned weights reported on fish receipts have been multiplied by 8 to supply round weights given here (Bureau of Marine Fisheries 1949).

Commercial digging has not been allowed in California since 1948.

Clam meats were imported from Mexico beginning in 1935. One of the main sources was San Quintin, 220 miles south of Tijuana (Alpin 1947b). Clams were collected by forks, placed in burlap bags, loaded in wheelbarrows, moved to shore, and shucked; the meats were then washed and placed in 5-gallon cans. From 86.7 thousand pounds to 53.4 million pounds were shipped annually to California from 1941 to 1947 (Table 2). Imports then ended because it became too costly to transport them to the cannery (Bureau of Marine Fisheries 1949).

Clams are collected by a variety of methods. The most common digging tool is a six-tined potato fork. Clams are placed in a sack attached to the waist. Some fishermen use a rake made of a pitch fork with an extended handle. A rope attaches the rake to the waist. In deeper water, fishing is done by towing a long-handled rake from a skiff. When a clam is struck, a diver recovers it. Using another method, skin divers wearing face masks and lying on paddle boards collect clams by locating them individually. When a siphon hole is seen, the clam is dug out of the sand with a short digging bar. Clams are sometimes located when the siphon holes are encountered by the bare feet of a wading fisherman. Fishermen also locate clams by looking for hydroid colonies, which occasionally grow on the edge of the shell of some clams.

The daily bag limit of clams has been reduced over the years from 200 in 1911 to 10 in 1985. As of 1986, they must be 4.5 inches or greater in length in San Luis Obispo County and south, and 5.0 inches or greater in Monterey County and north. All undersize clams must be returned to a hole (dug while looking for clams). The number of clam diggers in California is not known. An estimated 150,000 diggers were seen and over 75,000 lb of clams were caught on Pismo Beach on one weekend. In a 10-week period, 4 million pounds were taken from a 4-mile stretch of Pismo Beach (Frey 1971). As of 1986, sea otter predation has put an end to the fishery there.

ECOLOGICAL ROLE

The Pismo clam is a filter feeder on detritus, although living, one-celled organisms form a considerable portion of the diet (Frey 1971). Water taken in through the incurrent siphon passes over the gills where food particles are removed. The types of food utilized include phytoplankton (such as diatoms), bacteria, zooplankton, eggs and sperm, and detritus from disintegration of plants and animals. Half of the stomach contents is sand (Fitch 1950). In feeding a clam 3 inches long filters as much as 60 l of water per day. Intracellular digestion is done by phagocytic cells of the digestive diverticulum, aided by migratory phagocytes in the lumen of the alimentary canal (Coe 1947).

Since Pismo clams live buried in the sand, epizoic growth on the shell is rare--tufts of the hydroid Clytia bakeri occasionally live on the tip of the clam's exposed shell.

The Pismo clam has many predators including gulls, sharks, rays, and some surf fishes such as the California corbina (Menticirrhus undulatus). Rays use their wings to create a suction that pulls the clams from the sand. The rays then mouth the exposed clams and crush and shallow them (Frey 1971).

The moon snail, Polinices sp., eats clams up to 2 years old. It drills a hole in the shell with its rasping tongue and then inserts the tongue through the hole and eats the soft body of the clam. Cancer crabs, Cancer, have been observed to

crack the shell of clams up to 2.5 cm long with their front pincers.

At Sunset Beach, Santa Cruz County, Hawbecker (1939) watched gulls pick up sublegal size clams discarded by diggers, climb to an altitude of 9 to 12 m, and then drop the clams on the hard packed sand. The fall broke the shells and enabled the gulls to eat the clam.

In areas where sea otters (Enhydra lutris) forage, clam populations decreased significantly. A sea otter has been observed to eat 24 Pismo clams in 2.5 h (Stephenson 1977). Wendell et al. (1986) reported that a sea otter can consume 80 clams per day. Clams decreased from 6.5 to 0.5/m^2 at Moss Landing and from 0.55-0.80 clams/m^2 to 0.15 clams/m^2 at Zmudowski Beach from 1972 to 1974 (Stephenson 1977). Miller et al. (1975) estimated that otters ate 520,000 to 700,000 Pismo clams in one year at Monterey Bay.

Sea otters are directly responsible for the loss of the clam sport fishery in the Pismo Beach area (Wendell et al. 1986). The sport catch declined from 343,000 clams in 1978 to 0 in 1983.

Larval cestodes have been found in Pismo clams (Warner and Katkansky 1969). They occur as yellowish-white cysts, 3.2-3.8 mm in diameter. The cestodes have been identified as the larval stage of tapeworms in stingrays and skates. The parasites can stop the clam's sexual development but are not harmful to man if eaten (Frey 1971). Commensal pea crabs, occasionally found in the mantle cavity, feed on food particles collected by the clam's gills (Frey 1971).

ENVIRONMENTAL REQUIREMENTS

Little is known about the environmental requirements of the larval stage of Pismo clams. Fitch (1950) reported that only a small fraction of 1% of spawned eggs become mature clams. Causes for the mortality are unknown, but may include sudden changes in temperature and salinity.

Post larvae are known to die during heavy runoffs from rivers (Fitch 1950). Oil and other pollutants affect mortality. Red tide caused by a dinoflagellate bloom, as well as extremely cold weather, can kill young clams (Fitch 1950). Mortality rates for Pismo clams at Pismo Beach (Frey 1971), indicate that of 1,000 clams 0.5 year old, only 5 were still alive at age 7.5 (Table 3).

Pismo clams usually live in the intertidal zone on flat beaches of the open coast, but are sometimes found in entrance channels to bays, sloughs, and estuaries. Their normal depth in the sand is 5.2 to 15.6 cm (Armstrong 1965). They live in an environment of rapid, severe and forceful interaction of water and sand. They are slow diggers and are found in a characteristic position on the open coasts related to the waves: the front hinge and excurrent siphon face the ocean and the mantle edge and incurrent siphon face land. Clams in bays are oriented at random. They bury themselves by jetting water from the anterior of the shell while they bury the foot. The weight of the shell helps to carry the clam downward (Morris et al. 1980). The most productive areas for Pismo clams have extensive upwelling of cool oceanic water that brings with it inorganic nutrients essential for phytoplankton blooms (Coe and Fitch 1950).

Table 3. Pismo clam mortality rates (percentage of losses at Pismo Beach; Frey 1971).

Age of clams (years)	Number of clams	Percent loss	Number clams lost	Number clams remaining
0.5	1,000	55	550	450
1.5	450	45	202	248
2.5	248	29	72	176
3.5	176	34	60	116
4.5	116	52	60	56
5.5	56	68	38	18
6.5	18	72	13	5
7.5	5	--	--	--

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